National Aeronautics and Space Administration

Safe Human Expeditions Beyond Low Earth Orbit

A *NASA Engineering & Safety Center (NESC)* Study

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Space Weather Workshop

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Background

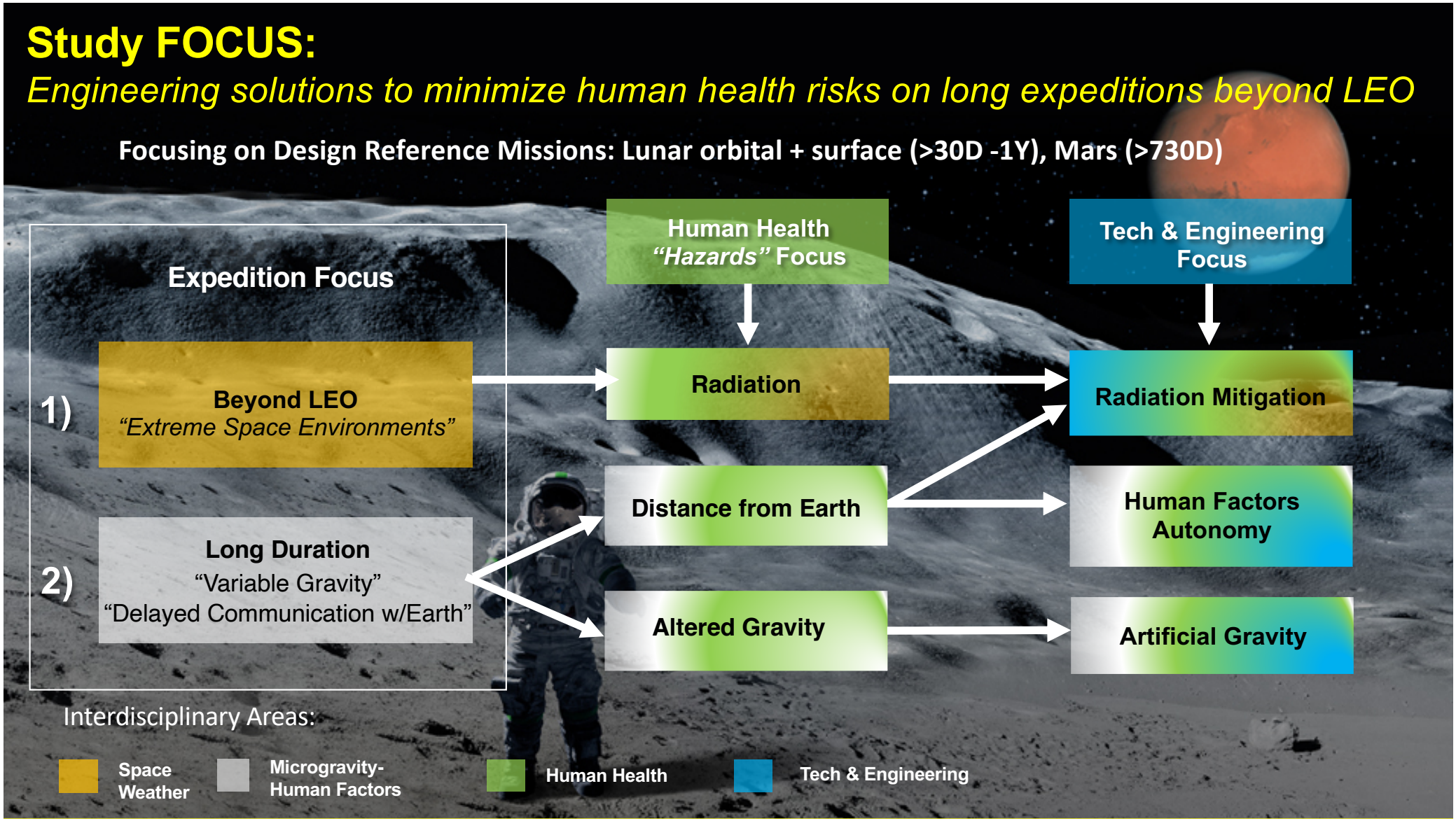
- Our knowledge and experience with long-term human expeditions ***beyond LEO*** is in its infancy.
- Apollo astronauts spent a **cumulative time of only 80 hours outside the lunar module and less than 3 months in space travel** over a period of 4 years.*
- NASA is planning extended duration **lunar missions (several months)** and expeditions to **Mars (several years)**.
- The Artemis-3 mission will take astronauts outside the Earth's protective magnetosphere for the first time since Apollo 17 (1972).
- **Space weather events** (solar flares and coronal mass ejections), as well as **galactic cosmic rays**, may pose serious threats to both astronaut health and spacecraft assets.
- Long duration flights with **variable gravity and delayed communication with Earth** pose additional risks.

* Physics Today 2020, Space Weather on the Moon, Larry Townsend

Study FOCUS:

Engineering solutions to minimize human health risks on long expeditions beyond LEO

Focusing on Design Reference Missions: Lunar orbital + surface (>30D -1Y), Mars (>730D)



NASA Human Systems Risk Board Summary

Hazards → Risks	Lunar Orbital +Surface (Long)	Mars Planetary
	30d-1yr	1-3 yrs
Radiation ← NESC Study Focus		
■ Cancer (LTH)	RC	RM
Non-Ionizing Radiation	A	A
Distance from Earth ← NESC Study Focus		
■ Inadequate Human Systems Integration Architecture	RM	RM
■ Inflight Medical Conditions	RM	RM
■ Inadequate Food and Nutrition	RM	RM
■ Ineffective or Toxic Medications	A	RM
Isolation & Confinement		
■ Cognitive or Behavioral Conditions	RM	RM
■ Psychosocial Adaptation within a Team	AM	RM
Altered Gravity ← NESC Study Focus		
■ Spaceflight Associated Neuro-ocular Syndrome - SANS (LTH)	A	RM
■ Renal Stone Formation	A	RM
■ Cardiac Rhythm Problems	AM	RM
■ Sensorimotor Alterations	RM	RM
■ Host-Microorganism Interactions	AM	RM
■ Bone Fracture	A	A
Space Adaptation Back Pain	A	A
Urinary Retention	A	A
■ Reduced Aerobic Capacity	AM	A
■ Reduced Muscle Size, Strength	AM	A
■ Orthostatic Intolerance	A	A
■ Venous Thromboembolism (CONCERN)	RC	RC
Hostile, Closed Environment		
■ Carbon Dioxide Exposure	A	RM
■ Injury from EVA Operations (LTH)	RM	RM
■ Injury from Dynamic Loads	RM	RM
■ Hypobaric Hypoxia	RM	RM
■ Decompression Sickness	RM	RM
■ Sleep Loss	RM	RM
■ Altered Immune Response	AM	RM
Electrical Shock	A	A
Hearing Loss (LTH)	AM	AM
Toxic Exposure	AM	AM
■ Celestial Dust Exposure	RM	RC

Risks

← Design Reference Missions (DRMs)

5 Hazards

↓

30 Risks

↓

Majority of risks

■ ■

Require mitigation for:

- *Long Lunar DRM*
- *Mars DRM*

Notes:

- Risk ratings are approved at the Human System Risk Board
- Risk ratings are for In-mission operations unless otherwise noted for Long-Term Health (LTH)
- Risk colors:
  - High LxC
  - Mid LxC
  - Low LxC
- Risk dispositions:
  - **A** Accepted
  - **AM** Accepted with monitoring
  - **RC** Requires characterization
  - **RM** Requires mitigation

By focusing on potential engineering solutions, several human health risks can be mitigated.

3 Study Tracks Being Integrated

Radiation Studies

Space Environments & Shielding

- Radiation environment comparison in LEO, lunar and Mars DRMs
- Shielding trade studies using vehicle models and transport codes
- Impact of SPE on operations including EVA
- Next generation space environment monitoring and forecast tools
- Predicting solar activity for upcoming solar cycle(s)

Fast Transit Trades

Fast Transit Trades Using Nuclear Thermal Propulsion

- Radiation exposure differences between fast transit and nominal transit including nuclear radiation exposure
- Trades in artificial gravity (AG) generation /exercise countermeasures in nominal transit vs fast transit without AG

Human System Integration

HSI Architecture Case Scenarios

- Develop standards for crew-carrying vehicles on long journeys to support increasingly earth-independent crew operations with increased reliance on automation, robotics, and intelligent technologies
- E.g. Re-thinking design and onboard operational support when SW events impact spacecraft, requiring crew intervention without assistance from Earth

The study will culminate in a NASA public workshop in September to gather and integrate community's input.

National Aeronautics and Space Administration

Save the Date!

Safe Human Expeditions Beyond Low Earth Orbit Workshop

September 14-16, 2021

Gilruth Conference Center

Houston, Texas

https://www.NASA.gov/NESC/workshops